



# Forest Health Protection

## Pacific Southwest Region



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To: District Ranger, Eagle Lake Ranger District, Lassen National Forest

Subject: Sporax®-ing conifer stumps in the North Moonlight Salvage Sale  
(FHP Evaluation # NE08-06)

At the request of Rick Crowther (Small Sales Officer, Eagle Lake RD), Bill Woodruff (FHP plant pathologist) evaluated the need to treat stumps with Sporax® during salvage of fire-killed trees from the area burned by the Moonlight Fire in the summer of 2007. It was determined that it is unnecessary to treat stumps because of the low risk of infecting the stumps and roots of removed trees with *Heterobasidion annosum*, the fungus which causes annosus root disease.

Sporax® is the fungicide applied to freshly-cut stumps to prevent annosus root disease. Once established in the root systems of pine trees, *H. annosum* is capable of spreading through those roots and then through the roots of adjacent trees (and subsequently regenerated trees); killing some of those trees for more than 30 years after the fungus originally colonizes the stumps. Generally, s-type *H. annosum* infects true fir and Douglas-fir and p-type *H. annosum* infects pine and incense cedar.

The objective of this evaluation is to document the reasons for not treating stumps with Sporax® after cutting trees in the North Moonlight Salvage Sale that were killed by the Moonlight Fire in September 2007. The areas to be salvage-logged are mixed conifer; white fir (77 % of the snags to be salvaged), ponderosa pine (11 %), incense cedar (4 %), red fir (4 %), sugar pine (3 %), and Douglas-fir (1 %). Cutting of the trees may begin as early as December 2008.

There are a number of reasons for not treating stumps with Sporax® during fire salvage:

- 1) The salvage trees have been dead for a number of years;
- 2) The salvage trees are true fir;
- 3) The salvage will result in a clear-cut;
- 4) The salvage trees are of small dbh; or,
- 5) Canopy openings resulting from annosus root disease are acceptable.

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### 1) The salvage trees have been dead for a number of years

After a tree is killed or weakened by fire, organisms enter the wood and start the decay process. Typically, insects tunnel under the bark or into the wood to lay their eggs. In the process, they physically destroy the wood in their paths and inoculate the wood with the bacteria and fungi carried on their exoskeletons. If the eggs hatch successfully, the resulting larvae tunnel through the wood, causing further damage and infections. When the larvae become adults, they emerge from the host tree carrying many of the fungi and bacteria on their exoskeletons that were established in the wood by their parents. These contaminated insects can fly to and bore into other dead or weakened trees and the cycle repeats itself. If too many years lapse after a tree is killed by fire the wood will be decayed to the point that it is useless for lumber. In much less time than it takes for decay organisms to destroy wood, fungi and bacteria can become established in the wood of a dead conifer and make that wood unfavorable to *H. annosum* colonization. This is because *H. annosum* competes poorly with most other fungi. The exact time it takes for the lower bole of a dead tree to be colonized by competing microbes which make the wood unsuitable for *H. annosum* is not known. However, in general, the longer a conifer is dead, the less susceptible its stump will be to *H. annosum*.

To better know how long it takes before stumps from dead pine are no longer susceptible to *H. annosum* infestation, a study was conducted in southern California on stumps from dead pine trees. (Kliejunas et al., 2006, Efficacy of Treating Live vs. Dead Stumps With Sporax® to Prevent Annosus Root Disease, USDA Forest Service FHP report R06-01, 8 pp.) The study determined that it was unnecessary to Sporax®-treat pine stumps from trees that were dead long enough to have lost all needles. (The study estimated that it took two years for bark beetle-killed trees to lose all needles.) By the time the Moonlight Fire pine trees are salvaged from Forest Service land, they will have been dead between one and two years and probably of low risk of initiating annosus root disease. However, until a study (similar to the Kliejunas study) on stumps of trees dead for less than two years is completed, it is not known how susceptible these stumps are to *H. annosum*.

The Kliejunas study did not address true fir stumps. As presented above, the decay process in a tree begins once any tree dies. Therefore it is reasonable to assume that, similar to pine trees, stumps from fir trees dead for two years will not support *H. annosum*.

### 2. The salvage trees are true fir

It is documented that annosus root disease commonly occurs in true fir. FSH R5 Supplement 3409.11-94-1 (effective 5/17/94, copy attached) states: "The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in forests surveyed in northern California." The handbook also states that in addition to stumps, which is the primary infection court for pine, "Infection in true fir may also occur through fire and mechanical wounds on the butt." Also, evaluations completed for the Keddie Project (FHP Evaluation # NE06-12) and Diamond Planning Area (FHP Evaluation # NE05-14), nearby on the Plumas NF, found annosus present in the true fir. Therefore, it is highly likely that s-type annosus root disease is already present in some of the true fir roots in the North Moonlight Salvage Sale, or it will occur as a result of the wounds caused by the fire. With annosus root disease present or imminent in the true fir

roots, it would be ineffective to treat the stumps with Sporax®, a preventative *H. annosum* fungicide.

Whether s-type annosus root disease is already present in the North Moonlight stands or introduced during salvage operations, it is possible to control the disease by planting pine seedlings in the areas occupied by true fir prior to the burn. Since pine seedlings are resistant to s-type *H. annosum*, the existing or introduced fir/s-type annosus will slowly die off in 30 to 50 years if only pine roots are in contact with the infected fir roots.

### 3. The salvage will result in a clear-cut

Clear-cuts are not favorable for annosus root disease. One reason for this is that *H. annosum* mycelium is killed after exposure to one hour at 104 F degrees. (see FSH R5 Supplement 3409.11-94-1) In clear-cut areas, lethal temperatures commonly occur on stump surfaces in the summer. A second reason why clear-cuts are not favorable to annosus root disease is the delayed time for developing roots from seedlings to reach infected roots of the stumps of the few successful annosus infections surviving the lethal temperatures on the stump surfaces. In other words, stumps/roots do sometimes get infected, but there are few places for the disease to spread after the roots become colonized with competing microbes and until the roots of adjacent regeneration comes in contact with the infected roots.

A long-term FHP study (Slaughter, retired UC Berkeley, unpublished) of an overstory removal harvest (cut in the 1950's) of mostly large pine near Swains Hole on the Eagle Lake RD followed the advancement of annosus root disease around large pine stumps (30-inch plus). The study showed that annosus root diseased occurred only in small areas around the larger stumps and became inactive approximately 30 years after onset. A 20 acre clearcut on the Plumas NF was surveyed in 1994 (Woodruff, unpublished) and only one dead ponderosa pine sapling was found killed by annosus from an infected stump. During the 2008 aerial mortality survey (Woodruff, unpublished), over ten thousand acres of pine plantations were observed (including the Fountain Fire) which had not been treated with Sporax®. Many of these plantations were on private ownership where salvage of dead trees normally begins immediately after the fire is suppressed. No mortality was observed in these plantations which would indicate that annosus root disease was active. This anecdotal evidence supports the claim that clearcuts, especially those resulting from wildfire, are not favorable to annosus root disease.

### 4) The salvage trees are of small dbh

In 2004, it was determined that *H. annosum* does not successfully colonize ponderosa pine stumps smaller than 14 inches in diameter (see John Kliejunas and Bill Woodruff, 2004, Pine Stump Diameter and Sporax® Treatment in Eastside Pine Type Stands, FHP Evaluation # R04-01, Region 5 S&PF). Furthermore, a FHP survey (Kliejunas, 1986) on the Modoc NF showed no pine stumps smaller than 18 inches infected with annosus. Also, *H. annosum* infection was found in 17% of the 18"- 22" pine stumps, 35% of the 22"-26" stumps, 41% of the 26"-30" stumps, 51% of the 30"-34" stumps, 60% of the 34"-38" stumps, 68% of the 38"-42" stumps, and 73% of the stumps larger than 42".

### 5) Canopy openings resulting from annosus root disease are acceptable

Stumps created during the North Moonlight Salvage Sale, will be exposed to both p-type and s-type spores of *H. annosum*. Without Sporax® the p-type spores could infect the

freshly-cut pine and incense cedar stumps and the s-type spores could infect the true fir and Doug-fir stumps. However not all stumps will be infected, as demonstrated by the Kliejunas (1986) survey discussed above in # 4). Moreover, a 1987 study on the Lassen National Forest showed that 15 percent of pine stumps became infected with *H. annosum* when stumps were not treated compared with up to 2 percent becoming infected when stumps were treated. On the Modoc NF, 130 miles north of the North Moonlight Salvage Sale, 1986-87 studies showed that 20 to 80 percent of non-boraxed stumps became infected compared with 2 to 4 percent of stumps treated with borax. (Note: Sporax® is the currently EPA-registered fungicide for preventing annosus root disease which is equivalent to borax which was previously used for that purpose.) Related studies showed that larger stumps are more likely to become infected with p-type *H. annosum* than small stumps.

If some of the stumps on the North Moonlight Salvage Sale are infected with *H. annosum*, with or without using Sporax®, a few small openings in the pine canopy (p-type annosus) and heart rot and cavities will develop in some of the true fir (s-type annosus) uninfected prior to the burn, could occur. Openings in the canopy and cavities in trees provide diversity in a forest and wildlife habitat. Even though the expected occurrence of new annosus root disease in the North Moonlight Salvage Sale is very low without using Sporax®, the small amount of annosus which may result would most likely benefit the ecosystem.

### Discussion

As shown above, the amount of resulting annosus root disease will depend on the size of the stumps and the length of time the trees are dead before salvage occurs. The mean diameter of ponderosa pine trees in the North Moonlight Salvage Sale is less than 21 inches and of true fir trees is less than 18 inches. Therefore, the expected amount of *H. annosum* stump infection without treating stumps with Sporax® is minimal. If live trees were cut, one would expect 17% of the stumps to become infected. Being that the salvage will be occurring over 15 months after tree death, the expected annosus infection will be much less than 17% and may even be zero.

The studies/surveys discussed above were mostly on pine stumps. In the absence of data, it has been assumed that similar infection rates will result on true fir stumps. Also, it has been shown that many true fir forests in California already have annosus root disease and it is expected that annosus root disease is already present in some of the true fir in the North Moonlight area. The planned salvage sale presents an opportunity to control the s-type annosus root disease already present in the fir roots by planting pine seedlings, which are resistant to s-type annosus, around the fir root systems following salvage.

If you have more questions, please contact me.

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## APPENDIX

### FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK

#### R5 SUPPLEMENT 3409.11-94-1

EFFECTIVE 5/17/94

#### CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

##### 62 - DISEASES.

###### 62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology. *Heterobasidion annosum* (*Fomes annosus*) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of *H. annosum* include Otrosina and Cobb 1989, and Smith 1993.

*Heterobasidion annosum* in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of *H. annosum* have distinct differences in host specificity. To date, all isolates of *H. annosum* from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but *H. annosum* is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113° F (45°C) and

mycelium in wood is killed after exposure for one hour at 104° F (40°C). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40° C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40°C in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H. annosum. Use the following similar symptoms for correct diagnosis:

- a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.
- b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.
- c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of *H. annosum* is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of *H. annosum* infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify *H. annosum* with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence

of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of *H. annosum*.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if *H. annosum* has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of *H. annosum*. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part

of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches (*Note: Revised to 14 inches: Ref. Kliejunas & Woodruff, FHP Report # R04-01*) or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches (*also revised to 14 inches*). These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

- a. The objectives and management direction for the stand.
- b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.
- c. An estimate of the cost-effectiveness of the treatment.
- d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are

costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

- a. Species Conversion. Because of host specificity of the 'S' and 'P' types of *H. annosum*, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand may be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.
- b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.
- c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.
- d. Stump Removal. Removal of stumps and roots infected with *H. annosum* would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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